As was discussed in the Background section of the present specification, US Patent No. 5,716,029 discloses a technique that adjusts the inertial attitude periodically while maintaining a fixed direction of electric propulsion thrust firing throughout each orbit. By way of summary, Spitzer et al. perform their maneuvers in a substantially fixed inertial attitude. Spitzer et al. force the final intermediate orbit to be a synchronous 24-hour orbit, wherein: (1) the semi-major axis of the final intermediate orbit is equal to the semi-major axis of the geosynchronous orbit, and (2) the inclination of the final intermediate orbit must be zero degrees (i.e., equal to the inclination of the geosynchronous orbit), and (3) the electric propulsion maneuvers to achieve geosynchronous orbit must be done in-plane (with no inclination change possible). Spitzer et al. do not teach anything regarding guidance maneuvers.

With specific reference to the Spitzer et al. patent, in its summary section, it discloses "a spacecraft and method for translating the spacecraft launched into an injection orbit about a central body and oriented in an inertial attitude to a synchronous orbit having a semi-major axis and a predetermined orbital plane. The apparatus includes a propulsion thruster oriented on the spacecraft to generate a thrust having a predetermined force on the spacecraft. The apparatus further includes a controller for controlling the timing of firing the propulsion thruster."

It is stated in Spitzer et al. patent that "The controller fires the propulsion thruster at apogees of intermediate orbits to successively increase the perigees thereof until the semi-major axis of an intermediate orbit is substantially equal to the semi-major axis of the synchronous orbit, thereby defining an initial transfer orbit for the spacecraft. The controller thereafter continuously fires the propulsion thruster to translate the orbit of the spacecraft from the initial transfer orbit to the synchronous orbit while maintaining the substantial equality of the synchronous semi-major axis and the transfer orbit semi-major axis."

It is also stated in Spitzer et al. patent that "The spacecraft is injected into a particular orbit and its inertial attitude is adjusted to maintain a desired orientation with respect to the sun. The otherwise unstable injection orbit is selected to offset the moments created by adjusting the spacecraft's attitude thereby maintaining a stable orbit. The maintenance of a constant sun angle is particularly applicable to spinner satellites and 3-axis cubic satellites in a spin stabilized mode."

It is also noted that the Spitzer et al. patent states that "electric propulsion thrusters in combination with chemical propulsion transfer orbit strategies provide an unacceptably long transfer orbit duration". It is also stated that "Thus, it is desirable to provide a transfer orbit apparatus and strategy using electric propulsion thrusters which provides acceptable transfer orbit duration for a given launch vehicle capability and a given payload". From these just-quoted statements, it appears that the Spitzer et al. patent teaches away from the combined use of both electrical and chemical thrusters.

Additional details regarding specific differences between the teachings of the Spitzer et al. patent and the present invention are discussed below. One issue involves spacecraft attitude during thrust.

The Spitzer et al. patent teaches that the spacecraft's attitude during the electric orbit raising mission (including <u>all</u> propulsion thrust maneuvers) is maintained in an "inertial attitude." Those skilled in the art recognize that "inertial attitude" refers to a fixed attitude in a non-moving coordinate system. The definition of inertial attitude is discussed in Section 18.3 of "Attitude Determination and Control" (James R. Wertz, D. Reidel Publishing Company, 1978). Wertz identifies a basic configuration of "<u>inertially referenced spacecraft</u> which maintain a nearly fixed attitude relative to a stellar target." Since the attitude is fixed the thrust vector must also be fixed in inertial space. Spitzer et al. constrains this thrust attitude even when <u>not</u> at apogee to still be generally along the direction of the velocity vector at apogee (see Table 1).

The basic attitude configuration utilized in the present invention maintains a fixed attitude relative to the thrust vector (steered) and the sun. This spacecraft attitude and the resultant thrust direction rotate in inertial space. When near apogee the thrust vector might be along the velocity vector at apogee but when the spacecraft is not at apogee the thrust vector is generally not aligned with the velocity vector at apogee.

Table 1- Attitude during Thrust

<u>Comparison Item</u>	<u>Present invention</u>	<u>Spitzer et al.</u>
Attitude	Continuously steered to direct the electric propulsion thrusters to optimally raise perigee, raise or lower apogee, and reduce inclination	Fixed inertial attitude

Another issue involves what is referred to as Phase 1: Semi-major axis of the intermediate orbits.

Spitzer et al. start from a geosynchronous transfer orbit (GTO) delivered by the launch vehicle and uses the spacecraft's propulsion system to thrust in a fixed inertial attitude around apogee. One purpose of the thrust is to raise the perigees of the intermediate orbits until their semi-major axis (orbital period) is substantially <u>equal</u> to the semi-major axis of the target final synchronous orbit (see Table 2).

Those skilled in the art will recognize that thrusting in a fixed inertial attitude over the orbit is sub-optimum in fuel efficiency (delivered ΔV) for raising perigee but may allow spinning autonomous attitude control.

The present invention starts from a geosynchronous transfer orbit (GTO) delivered by the launch vehicle and thrusts with chemical propulsion in a steered attitude around apogee.

One purpose of this chemical thrust is to quickly raise the perigees of the intermediate orbits until the perigee is sufficiently high enough to reduce the damaging effects of the Van Allen radiation belts on the spacecraft to acceptable levels. At the time Phase 1 stops the semi-major axis (orbital period) of the final intermediate orbit is substantially less than the semi-major axis of the target final synchronous orbit.

Table 2- Phase 1 of Orbit Raising

Phase 1: Perigee Raising/Inclination Reduction

Comparison Item	Present invention	Spitzer et al.
(1) Attitude	Steered to direct the chemical propulsion thrusters to optimally raise perigee	Fixed inertial attitude
(2) In-plane thrust attitude	Steered near orbit apogee to optimally raise perigee	Maintained inertially along the direction of velocity vector at apogee to only raise perigee as spacecraft moves around the orbit
(3) Out-of-plane thrust attitude	Maintained at constant out-of-plane angle near apogee to reduce inclination	Maintained inertially at a constant out-of-plane angle throughout the orbit
(4) Continuous thrust	No (thrust near apogee only)	No (But thrust can be as much as 19 hours out of 22 hour orbit - lines 51-54, col. 7)
(5) Thrust at perigee	No	No
(6) Semi-major axis of final intermediate orbit	Subsynchronous	Synchronous
(7) Inclination of final intermediate orbit	Above target orbit (i > zero degrees)	Equal to target orbit (i = zero degrees)

Another issue involves what is referred to as Phase 1: Inclination of the intermediate orbits.

Spitzer et al. teaches (page 7 lines 25-56 and page 8 lines 1-7) that a second purpose of the thrust around apogee in Phase 1 of Orbit Raising is to reduce the inclination to zero degrees at the same time perigee reaches the semi-major axis of the geosynchronous orbit (Table 2). Spitzer et al. accomplish this decrease in inclination by allowing a component of the thrust vector to be inertially fixed partly out-of-plane as the spacecraft moves around its orbit. Those skilled in the art will recognize that maintaining this inertial attitude while thrusting around the apogee node can reduce inclination but if thrust is maintained near the perigee node inclination

will actually start to increase again. That is the fundamental reason that Spitzer et al. teaches the application of thrust only around apogee in this phase of the electric orbit raising mission.

It is also noted that maintaining the Spitzer et al. fixed inertial thrust attitude in-plane along the velocity vector at apogee with a constant out-of-plane component is inherently inefficient in terms of fuel cost and time to reach target synchronous orbit. At anti-nodes, for example, the out-of-plane thrust will have no influence on the inclination but will still waste fuel.

The chemical thrust maneuvers at apogee are partly out-of-plane in the present invention so they do remove some inclination. However, the inclination at the conclusion of this phase is substantially greater than the inclination of the target geosynchronous final orbit.

Another issue is with regard to what will be referred to as Phase 2: Semi-major axis of the intermediate orbits.

In Phase 2 of the EOR mission Spitzer et al. teach application of continuous thrust in an inertial attitude to reduce the intermediate orbit eccentricity while maintaining the substantial equality of the final and intermediate orbit's semi-major axis. Again, though a fixed inertial attitude along the velocity vector at apogee works to raise perigee and lower apogee it is not the optimum direction to thrust around the orbit in terms of the shortest transfer orbit duration (TOD) or maximum fuel efficiency.

The present invention steers the electric propulsion thrust vector to optimally raise the orbit (perigee increases but apogee may also initially increase) to the target geosynchronous orbit. The present invention also recognizes that disturbances must be accounted for in the mission plan (e.g. lower than expected thrust; unplanned coast arcs; etc.).

Another issue involves what is referred to as Phase 2: Inclination of the intermediate orbits.

Spitzer et al. teaches that thrust is continuously applied in an inertial attitude around the entire orbit in Phase 2 of the orbit raising. Though a fixed inertial attitude accomplishes the in-plane objectives it will not remove much inclination. All of the desired inclination reduction is accomplished in Phase 1 of the orbit raising and Phase 2 is performed entirely in-plane.

The present invention steers the electric propulsion out-of-plane thrust vector to remove inclination when effective (near the nodes) and to be essentially in-plane when not effective (near the anti-nodes). The nominal inclination reaches the final target orbit inclination at essentially the same time as the intermediate orbit eccentricity reaches the final orbit eccentricity.

Table 3 – Phase 2 of Orbit Raising

Phase 2: Perigee Raising/Inclination Reduction

Comparison Item	Present invention	Spitzer et al.
(1) Propulsion	Electric	Electric
(2) Attitude	Steered	Fixed inertial attitude
(3) In-plane	Steered around the orbit to	Maintained inertially along the

thrust attitude upon mission phase)	optimally raise perigee, raise or lower apogee (dependent apogee, lower apogee near perigee	direction of velocity vector at apogee to raise perigee near while maintaining a basically unchanging semi-major axis
(4) Out-of-plane thrust attitude	Steered to optimally reduce inclination(near zero only near the anti-nodes)	No out-of-plane component of thrust because fixed inertial attitude
(5) Continuous thrust	Yes	Yes
(6) Thrust at perigee	Yes	Yes
(7) Semi-major axis of initial and final intermediate orbits	Initial - subsynchronous Final - synchronous	Initial - synchronous Final - synchronous
(8) Inclination of initial and final intermediate orbit	Initial - Above target orbit (i > zero degrees) Final - Equal to target orbit (i = zero degrees)	Initial - Equal to target orbit (i = zero degrees) Final - Equal to target orbit (i = zero degrees)

Another issue involves what is referred to as the orientation of the spacecraft to the sun. Both Spitzer et al. and the present application describe methods for keeping the solar arrays essentially normal to the sun to provide sufficient power run the electric thrusters and the mission.

Spitzer et al. performs all thrust maneuvers in an inertial attitude (essentially along the velocity vector at apogee with constant out-of-plane components for some mission phases). At columns 11 and 12, Spitzer et al. describe a method of using a stable orbit and small adjustment of the inertial attitude to produce a 1 degree per day movement to keep synchronized with the sun. Spitzer et al. also teaches the use of both a spinning satellite and a spin stabilized 3-axis satellite (page 10, lines 28-49). However, the latter's solar panels cannot be adjusted while spinning because of the damaging torque that would result.

The present invention performs all thrust maneuvers in a 3-axis attitude that rotates in inertial space. Using Sun-ΔV steering (Figs. 11 and 12) the satellite is rotated around the spacecraft Z axis until the solar array axis is normal to the sun line. This rotation can be as much as 360 degrees per orbit and is distinctly different from anything taught by Spitzer et al. The solar arrays can be safely adjusted because the non-spinning 3-axis satellite has no torque concerns.

Another issue involves what is referred to as selectively firing the chemical thrusters to achieve final geosynchronous orbit.

Spitzer et al. does not teach any method for guiding the satellite to its intended on-orbit location in the presence of practical disturbances to the nominal mission plan. Practical

disturbances include off-nominal electric thruster performance such as lower thrust or Isp; unplanned coast periods; ground station outages; commanding errors; attitude pointing errors; etc.

The present application describes a method using chemical thruster propulsion maneuvers to perform the on-station guidance and rapidly achieve the final target orbit because of the relatively high acceleration capability of chemical thrusters.

Comparison Item	Present invention	Spitzer et al.
Guidance for disturbances to mission plan	Chemical and/or electric propulsion maneuvers correct for such things as parameter variations, errors and unplanned events	Not addressed

From the above arguments, and with specific regard to independent Claim 1, it is respectfully submitted that the Spitzer et al. patent does not disclose or suggest the steps of "firing the chemical propulsion thrusters at apogees of intermediate orbits, starting from the transfer orbit initiated by the launch vehicle, to successively raise perigees of the orbit until the spacecraft perigee clears the Van Allen radiation belts, and where the semi-major axis of the intermediate orbit is substantially less than the semi-major axis of the final orbit, and where the inclination of the intermediate orbit is substantially greater than the inclination of the final orbit", "continuously firing the electric propulsion thrusters to raise the orbit of the spacecraft from the orbit achieved by the chemical propulsion thrusters firing step to near geosynchronous orbit by steering the thrust vector both in-plane and out-of-plane while rotating the spacecraft body and steering the solar array to maintain the sun's illumination on the solar array" and "firing selected ones of the thrusters to achieve final geosynchronous orbit" as is recited therein.

In view of the above, it is respectfully submitted that Claim 1 is not disclosed or suggested by the Spitzer et al. patent. Accordingly, withdrawal of the Examiner's rejection and allowance of Claim 1 is respectfully requested.

Dependent Claims 2-22 are considered patentable based upon the patentability of Claim 1 from which they depend. Therefore, withdrawal of the Examiner's rejection and allowance of Claims 2-22 is respectfully requested.

Independent Claim 23 contains substantially the same limitations as are recited in Claim 1 (which are implemented in a processor) and is considered patentable over the Spitzer et al. patent for the same reasons as Claim 1. Therefore, it is respectfully submitted that Claim 23 is not disclosed or suggested by the Spitzer et al. patent. Accordingly, withdrawal of the Examiner's rejection and allowance of Claim 23 is respectfully requested.

Dependent Claims 24-29 are considered patentable based upon the patentability of Claim 23 from which they depend. Therefore, withdrawal of the Examiner's rejection and allowance of Claims 24-29 is respectfully requested.

The prior art made of record and not relied upon is considered pertinent to Applicant's disclosure to the extent indicated by the Examiner

In view of the above, it is respectfully submitted that Claims 1-29 are not anticipated by, nor are they obvious in view of, the cited patents, taken singly or together, and are therefore allowable. Accordingly, it is respectfully submitted that the present application is in condition for allowance. Reconsideration of this application and allowance thereof are earnestly solicited.

Respectfully Submitted,

Kenneth W. Float

Kenneth W. Float
Registration No. 29,233

The Law Offices of Kenneth W. Float
Office address: 2 Shire, Coto de Caza, CA 92679
Mailing address: P. O. Box 80790, Rancho Santa Margarita, CA 92688
Telephone: (949) 459-5519
Facsimile: (949) 459-5520